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Making Multitemporal Work

Randolph H. Wynne, Christine E. Blinn, Kevin J. Boyle, Evan B. Brooks, Harold E. Burkhart, John W. Coulston, Thomas R. Fox, Klaus Moeltner, S. Seth Peery, and Valerie A. Thomas

Presented to Landsat Science Team
Sioux Falls, South Dakota
October 30, 2013

- Is crowd sourcing a reliable and cost-effective solution to removing clouds and cloud shadows that remain subsequent to the application of automated algorithms?
- How can Fourier series best be used to create smooth periodic time series of Landsat data?
- Using smooth periodic time series generated from Fourier regression or (as necessary) (E)STARFM (Gao et al. 2006, Zhu et al. 2010), how can both gross and subtle changes to land use / cover be detected reliably using from one to three additional observations?
- How well do empirical (Flores et al., 2006) and physically-based (Ganguly et al., 2012) algorithms for leaf area index (LAI) generation estimate LAI in intensively-managed pine ecosystems? How can they be improved?
- Using the new tree canopy product as a case study, how can the precision of vegetation continuous field products be estimated in a robust and computationally-efficient manner?


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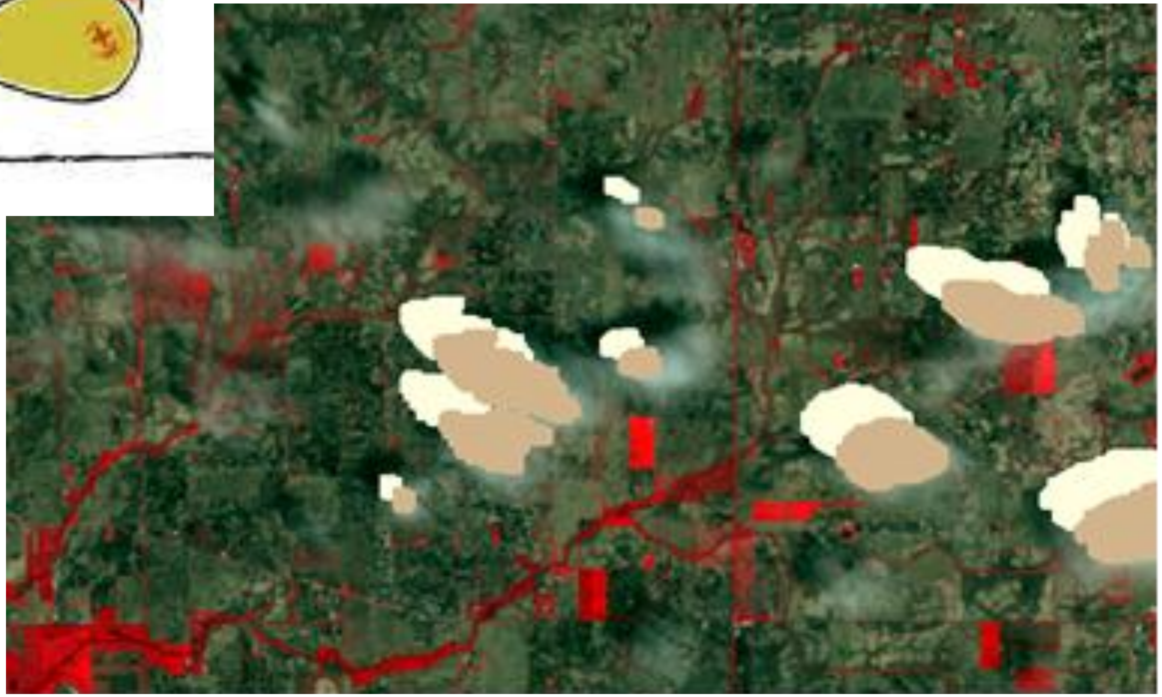

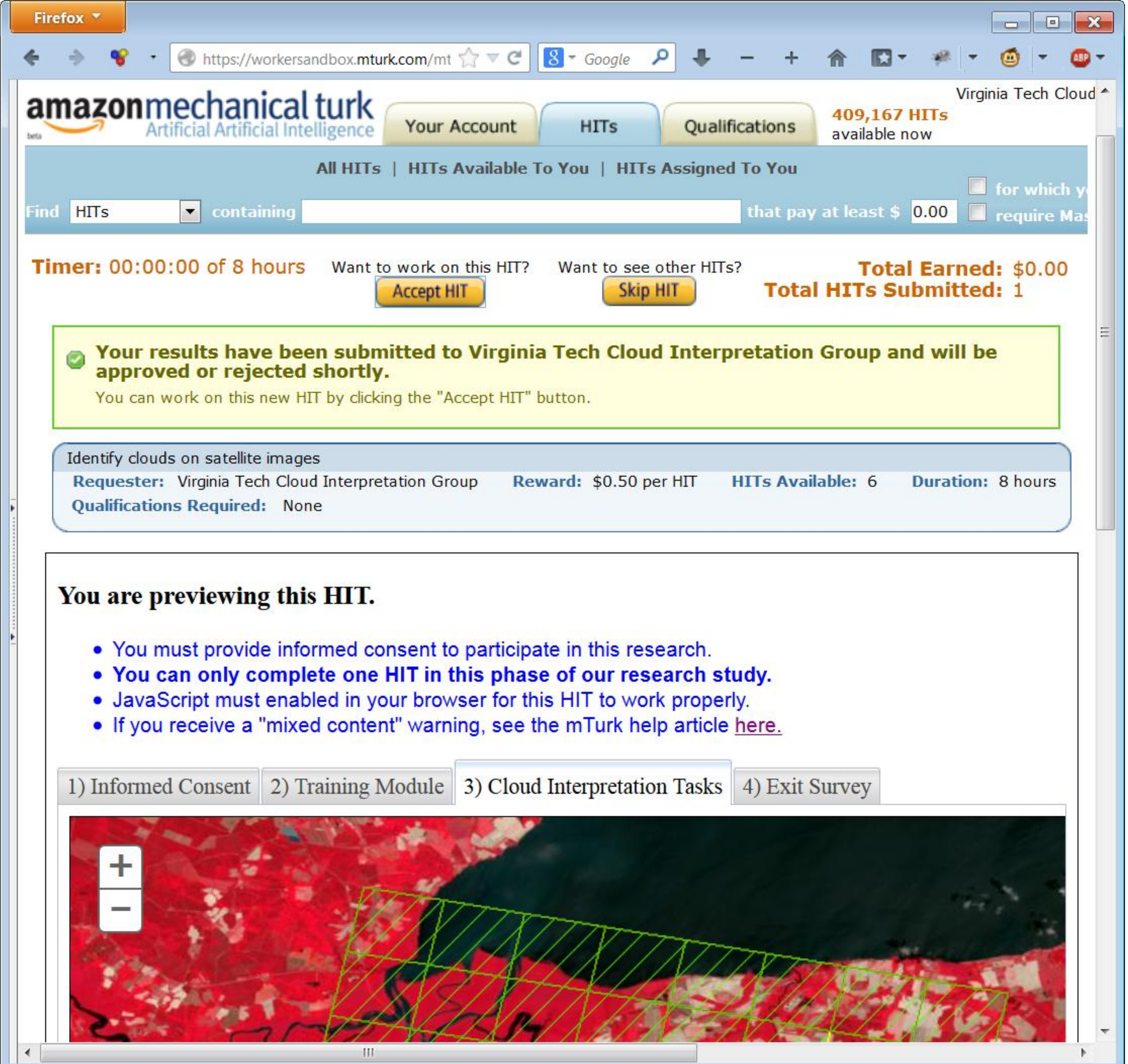
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HITs
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Virginia Tech Cloud
409,167 HITs
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All HITs | HITs Available To You | HITs Assigned To You
Find
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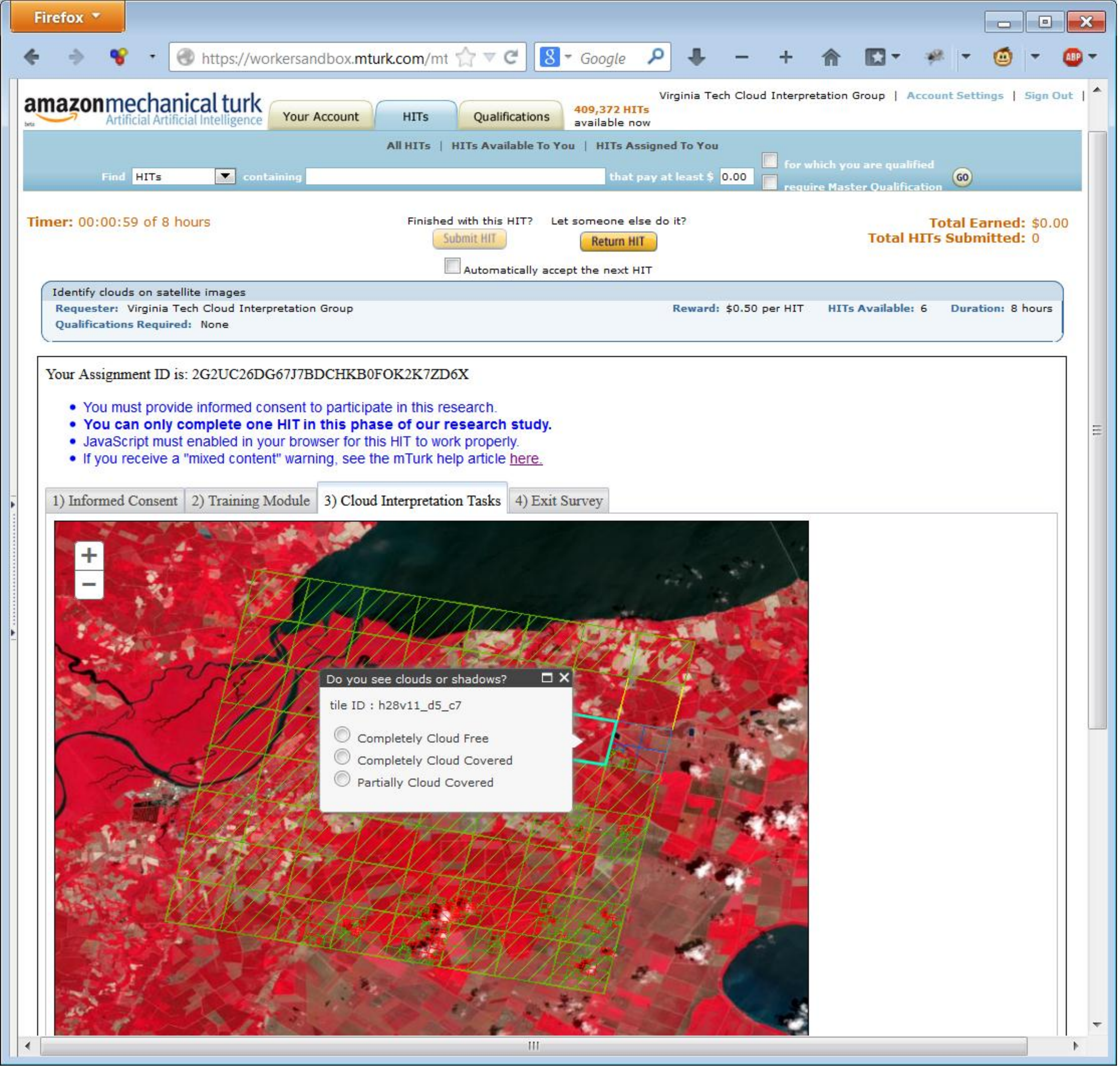
Timer: 00:00:00 of 8 hours
Want to work on this HIT?
Accept HIT
Want to see other HITs?
Skip HIT
Total Earned: $0.00
Total HITs Submitted: 1
Your results have been submitted to Virginia Tech Cloud Interpretation Group and will be approved or rejected shortly.
You can work on this new HIT by clicking the "Accept HIT" button.
Identify clouds on satellite images
Requester: Virginia Tech Cloud Interpretation Group
Reward: $0.50 per HIT
HITs Available: 6
Duration: 8 hours
Qualifications Required: None
You are previewing this HIT.
You must provide informed consent to participate in this research.
You can only complete one HIT in this phase of our research study.
JavaScript must enabled in your browser for this HIT to work properly.
If you receive a "mixed content" warning, see the mTurk help article here.
1) Informed Consent
2) Training Module
3) Cloud Interpretation Tasks
4) Exit Survey



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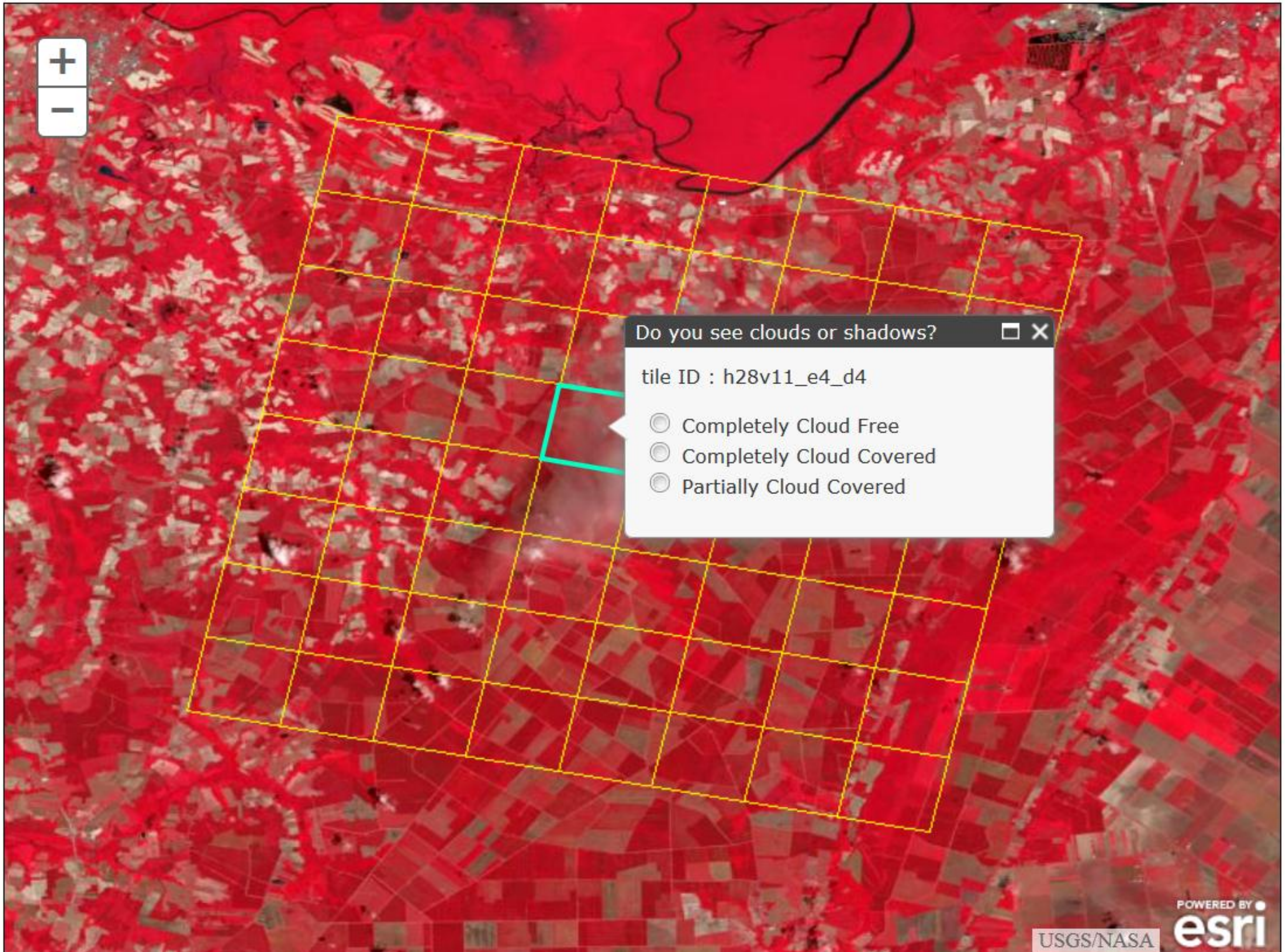
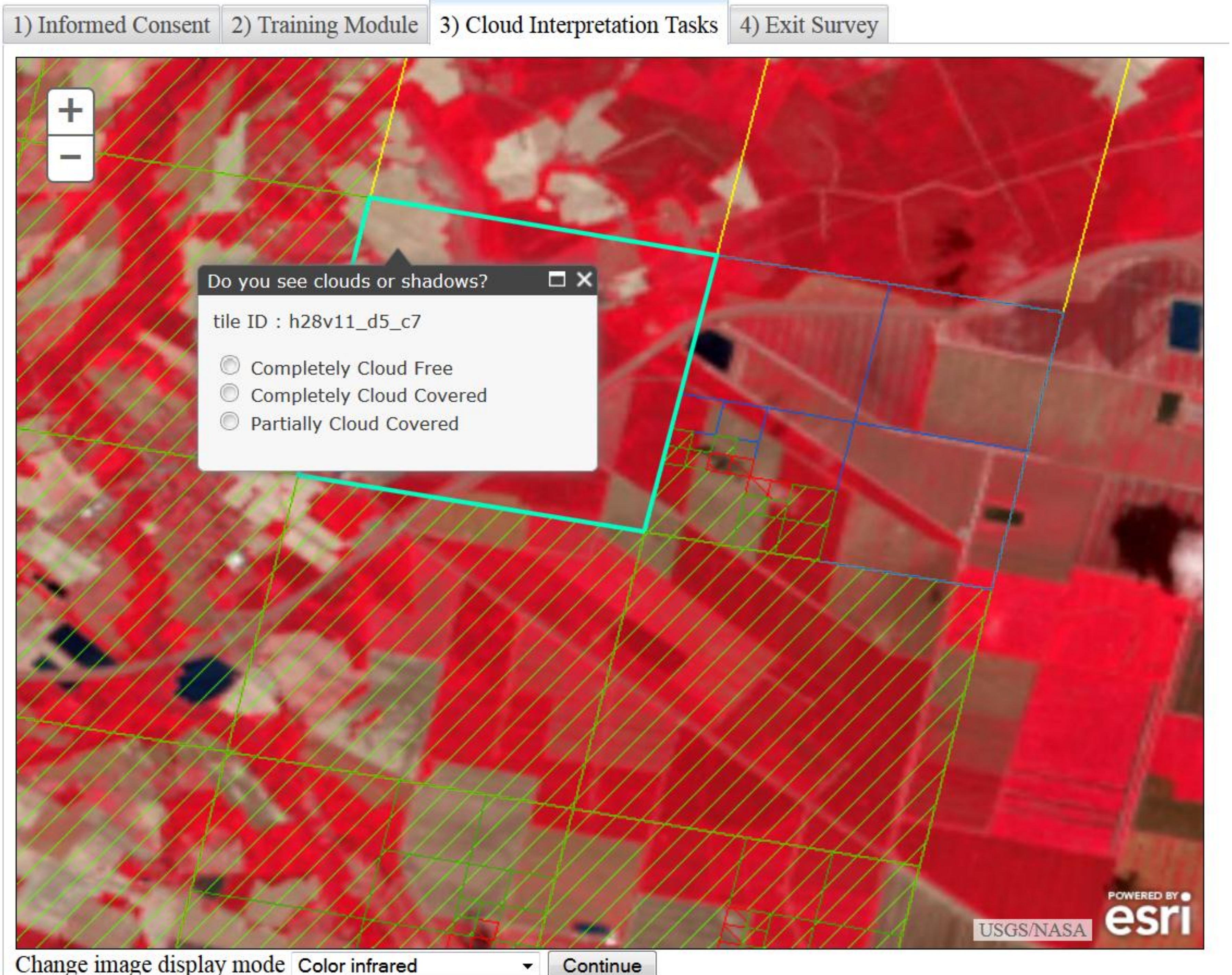
HITs
Qualifications
409,372 HITs
available now
Virginia Tech Cloud Interpretation Group | Account Settings | Sign Out |
All HITs | HITs Available To You | HITs Assigned To You
Find HITs containing that pay at least $ 0.00
for which you are qualified
require Master Qualification
GO
Timer: 00:00:59 of 8 hours
Finished with this HIT?
Submit HIT
Let someone else do it?
Return HIT
Automatically accept the next HIT
Total Earned: $0.00
Total HITs Submitted: 0
Identify clouds on satellite images
Requester: Virginia Tech Cloud Interpretation Group
Qualifications Required: None
Reward: $0.50 per HIT
HITs Available: 6
Duration: 8 hours
Your Assignment ID is: 2G2UC26DG67J7BDCHKB0FOK2K7ZD6X
You must provide informed consent to participate in this research.
You can only complete one HIT in this phase of our research study.
JavaScript must enabled in your browser for this HIT to work properly.
If you receive a "mixed content" warning, see the mTurk help article here.
1) Informed Consent
2) Training Module
3) Cloud Interpretation Tasks
4) Exit Survey
Do you see clouds or shadows?
tile ID : h28v11_d5_c7
Completely Cloud Free
Completely Cloud Covered
Partially Cloud Covered

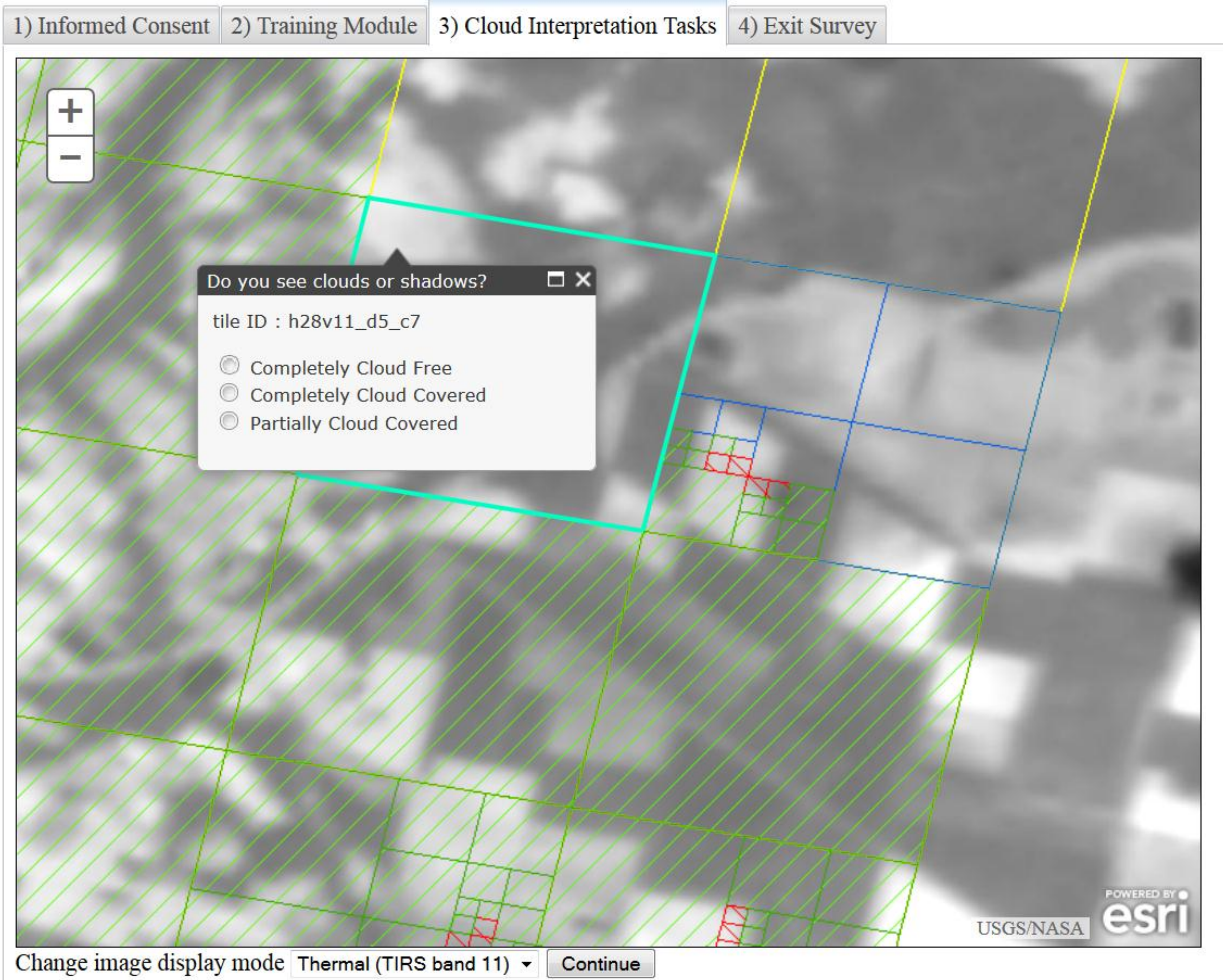
Task 3 of 3: Find clouds in this scene. When you have finished the task, press the Continue button.

1) Informed Consent | 2) Training Module | 3) Cloud Interpretation Tasks | 4) Exit Survey



Change image display mode Color infrared Continue


1) Informed Consent
2) Training Module
3) Cloud Interpretation Tasks
4) Exit Survey
+
−
Do you see clouds or shadows?
tile ID : h28v11_d5_c7
Completely Cloud Free
Completely Cloud Covered
Partially Cloud Covered
USGS/NASA
POWERED BY
esri
Change image display mode
Color infrared
Continue


1) Informed Consent
2) Training Module
3) Cloud Interpretation Tasks
4) Exit Survey
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Do you see clouds or shadows?
tile ID : h28v11_d5_c7
Completely Cloud Free
Completely Cloud Covered
Partially Cloud Covered
USGS/NASA
POWERED BY
esri
Change image display mode
Thermal (TIRS band 11)
Continue

A sample scene

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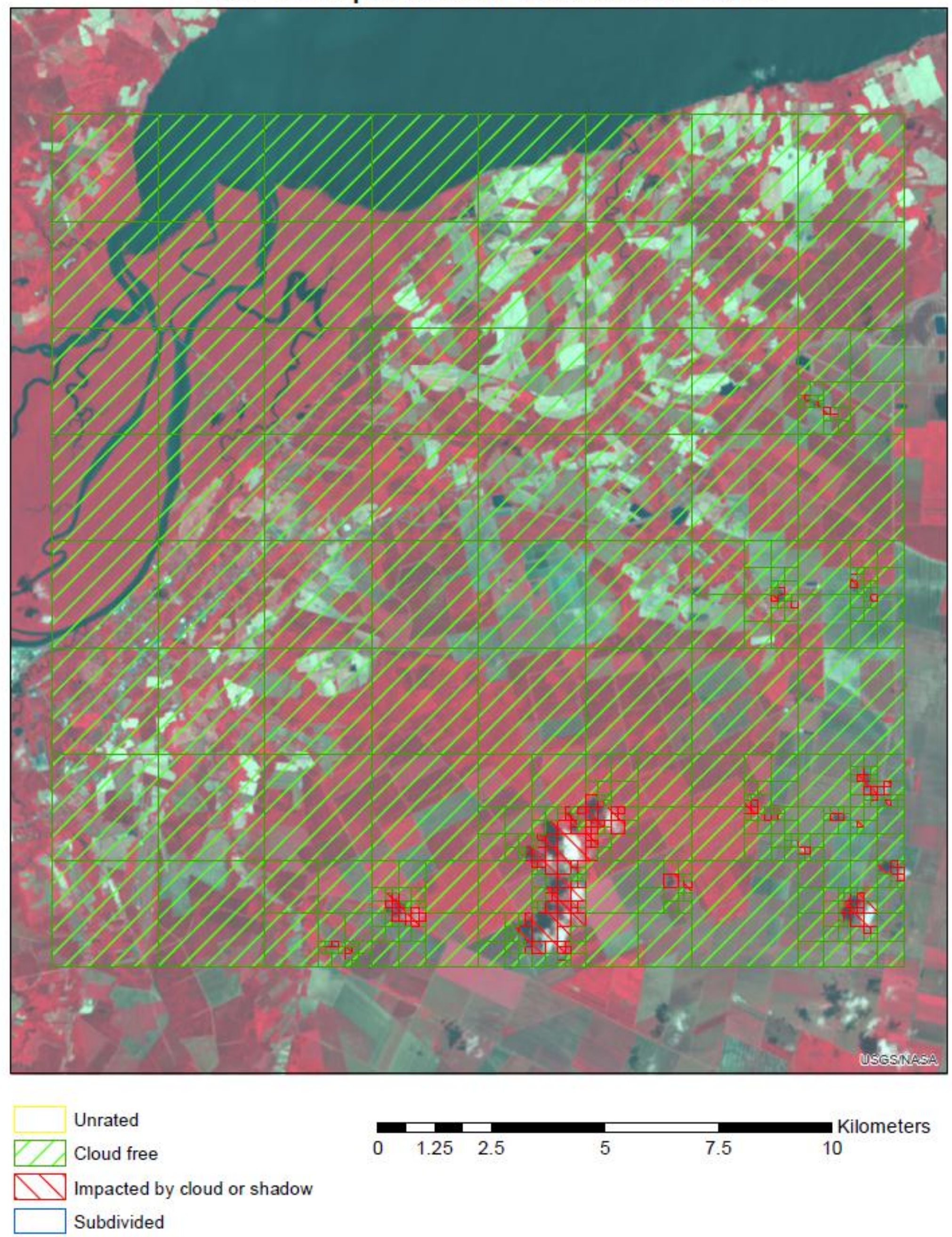
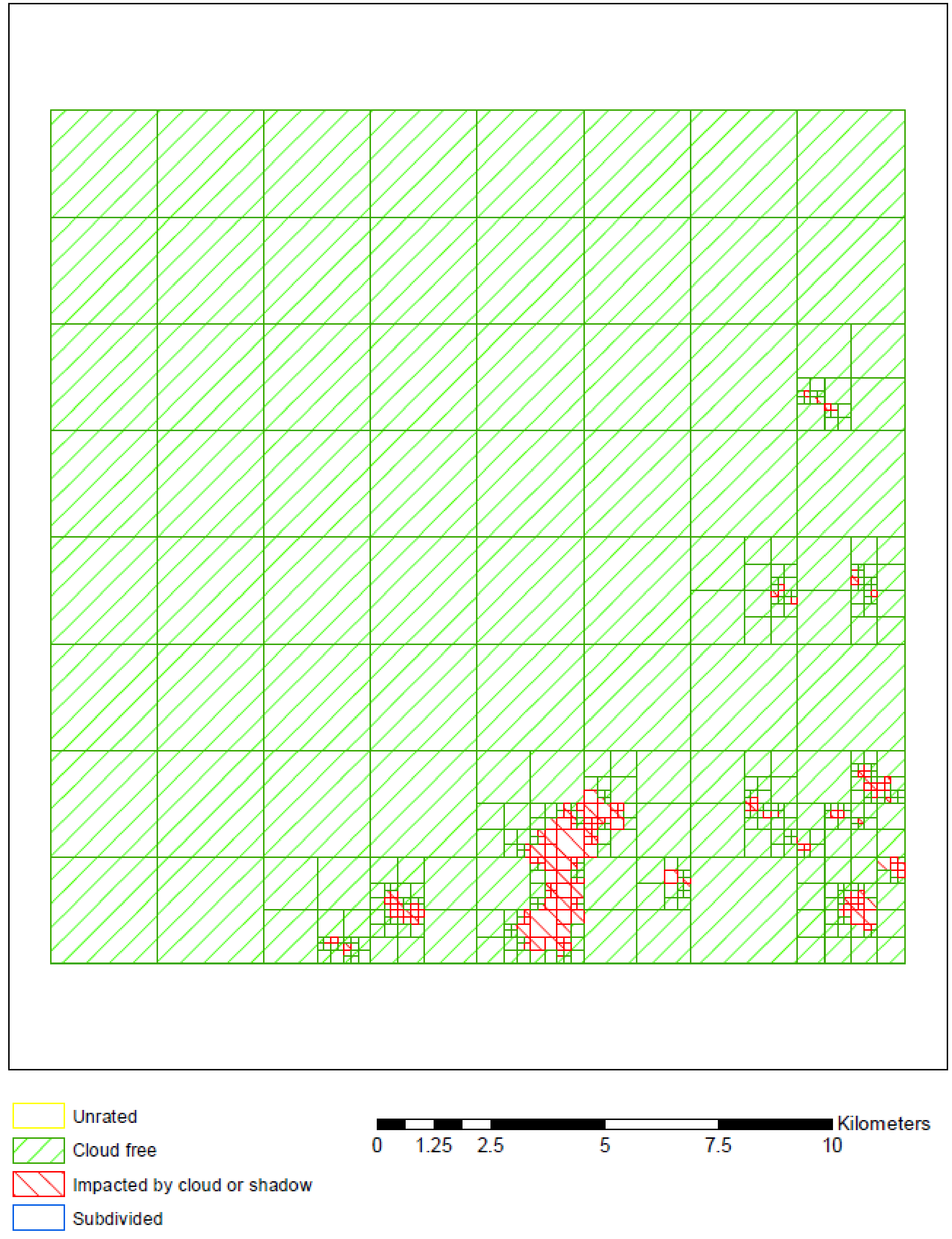
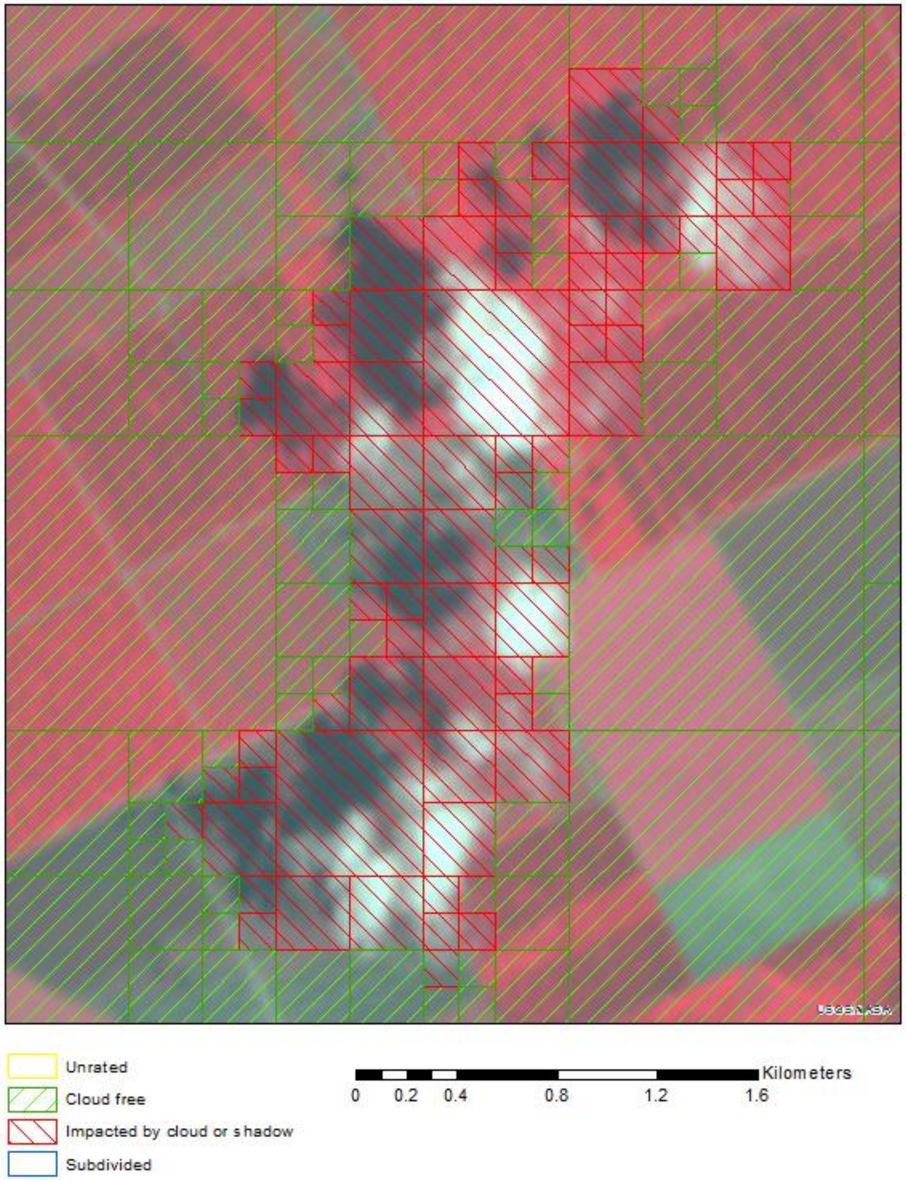
Full Interpretation Task over CIR



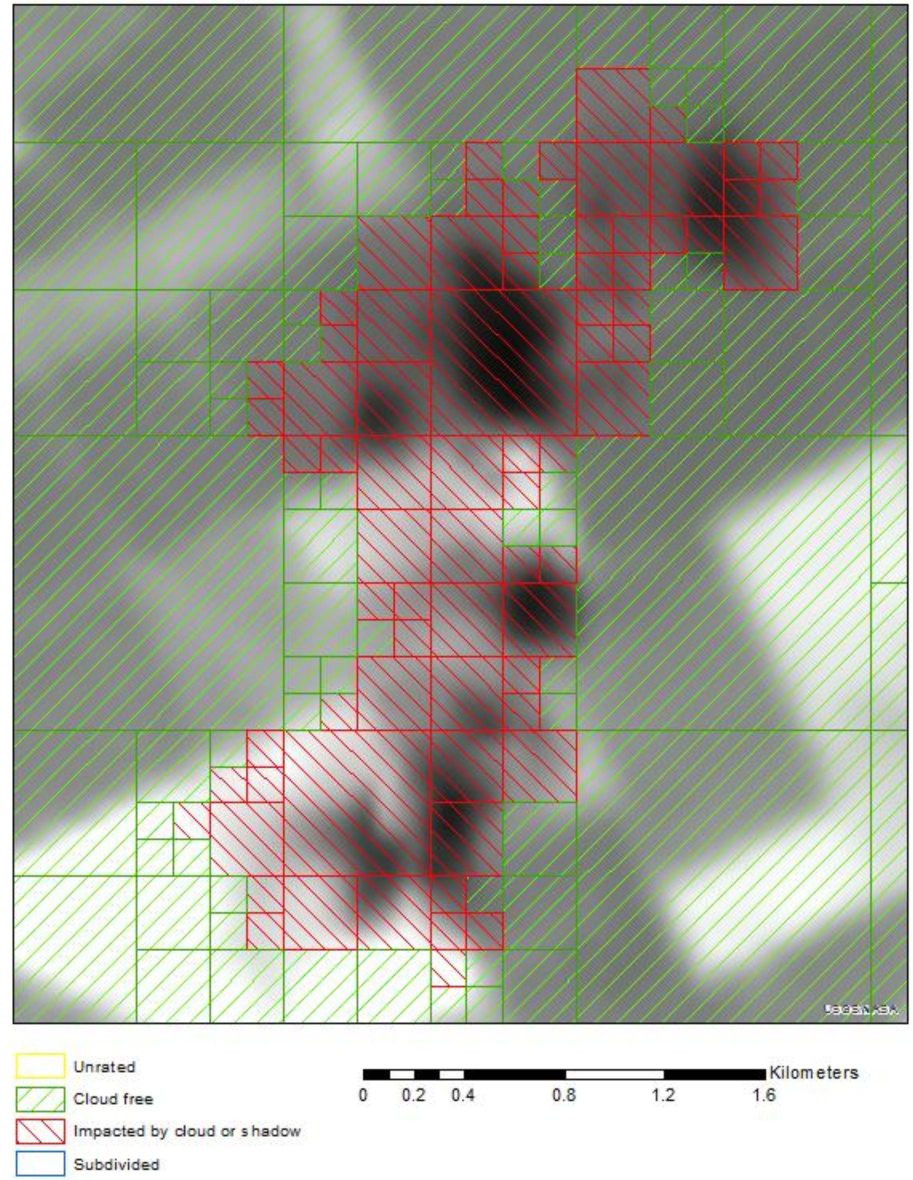
A Complete Interpretation Task (64 --> 517 tiles)



Interpretation detail view over CIR



Interpretation detail view over TIRS



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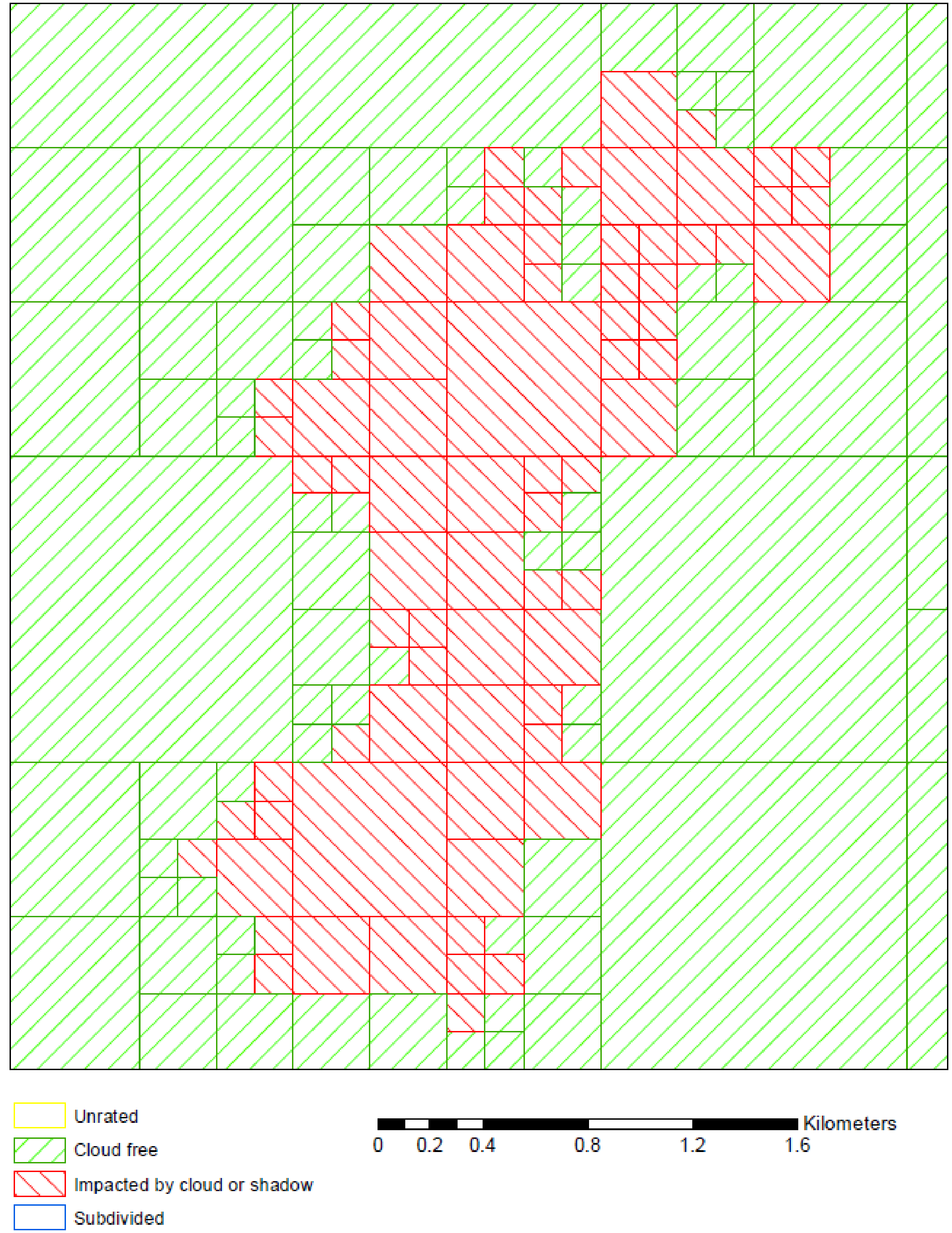
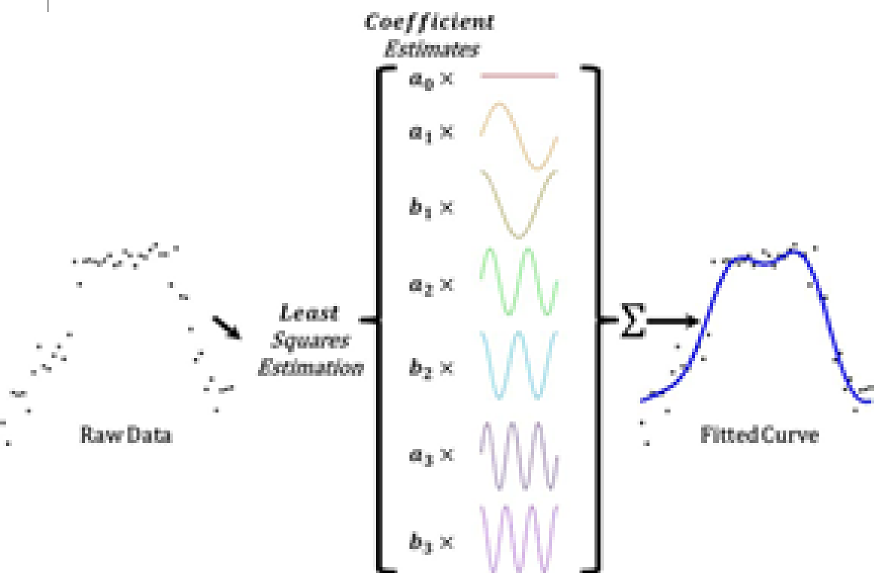
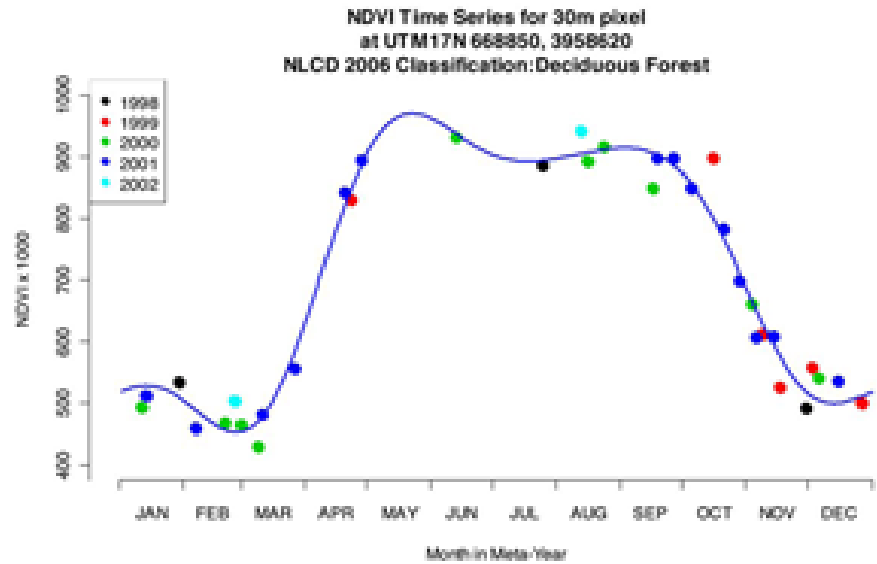
A cloud as a quadtree



Talking Points: Architecture

- The infrastructure that we have developed for the current use case of identifying clouds on Landsat scenes has the potential to serve as a general purpose platform for the integration of geospatial crowdsourcing tasks into mTurk.
- The quadtree implementation we use allows for interpretation at varying scales.
- mTurk provides a workforce. Our system provides a means to present geospatial problems, hosted in ArcGIS Server, to that workforce as External Questions.


Coefficient Estimates
$a_0 \times$
$a_1 \times$
$b_1 \times$
$a_2 \times$
$b_2 \times$
$a_3 \times$
$b_3 \times$
Raw Data
Least Squares Estimation
Σ
Fitted Curve


NDVI Time Series for 30m pixel
at UTM17N 668850, 3958620
NLCD 2006 Classification:Deciduous Forest
1998
1999
2000
2001
2002
NDVI x 1000
400
500
600
700
800
900
1000
JAN
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DEC
Month in Meta-Year

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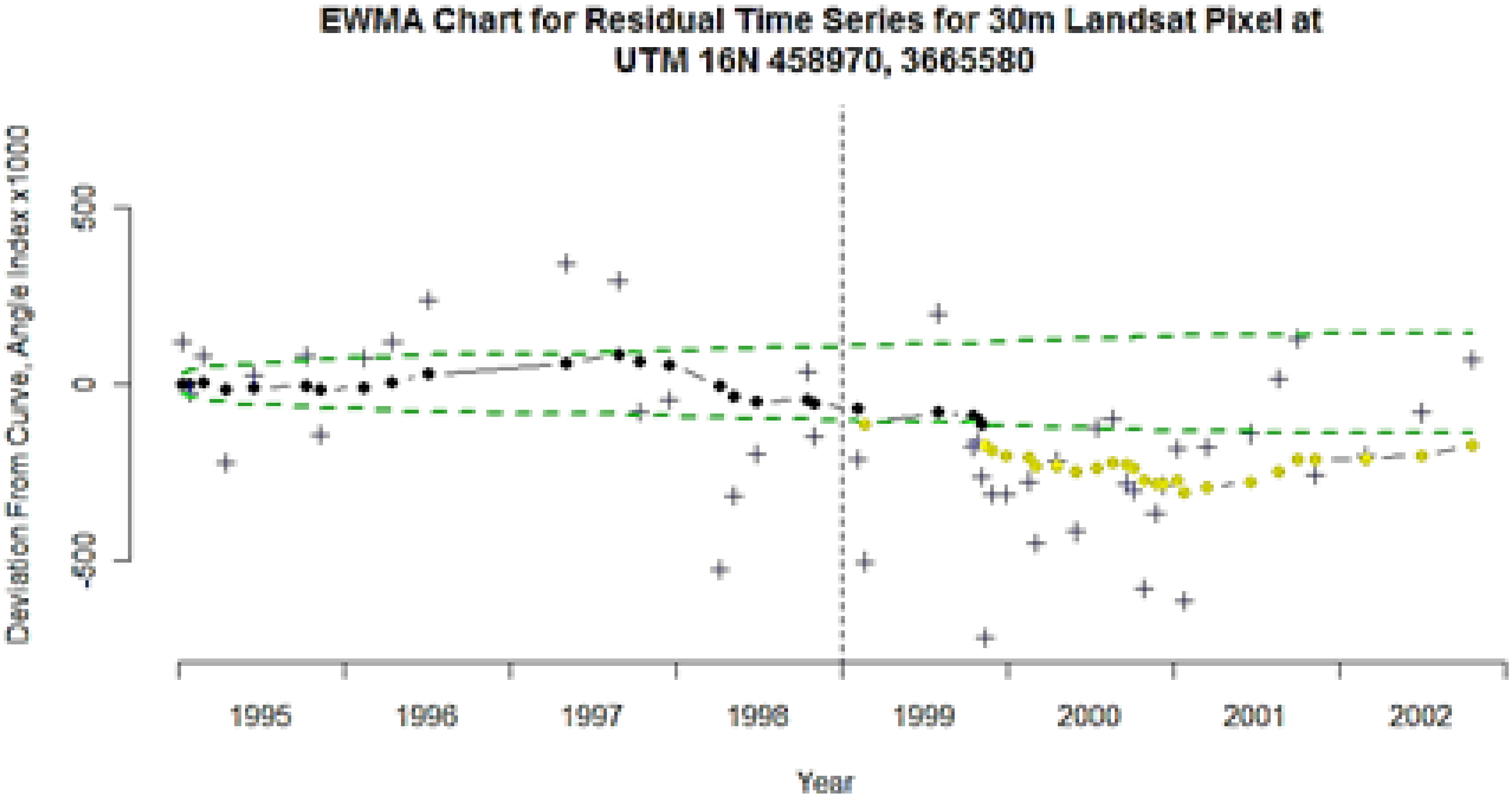

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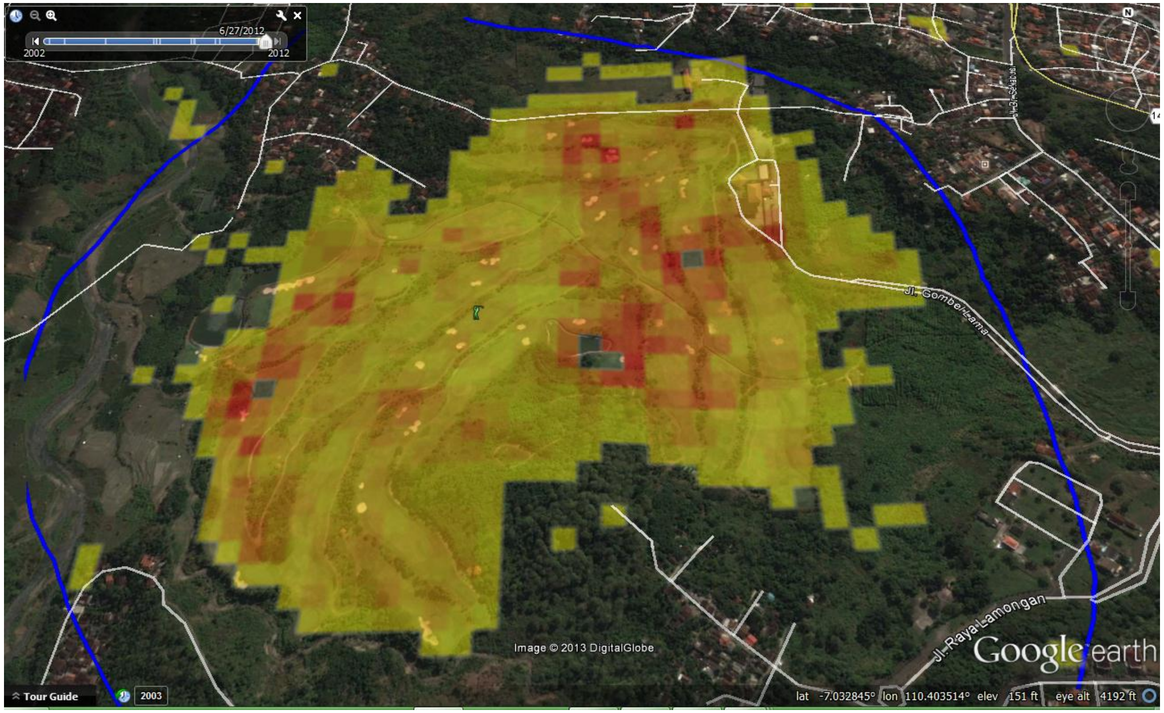
Projects

- **Current Activity**
  - Exponentially Weighted Moving Average Change Detection (EWMACD) in Java, Indonesia
    - Collaboration with Jeffrey Cardille, Department of Geography, Université de Montréal, Montreal, Quebec, Canada
  - Forest Inventory and Analysis (FIA) in Carolinas, USA
    - Collaboration with John Coulston, USDA Forest Service FIA Program, Southern Research Station
    - Change in vegetative cover/dynamic parameter estimation (via EWMACD)
    - Forest biophysical parameter estimation (via harmonic regression)

- **On Deck**
  - Harmonic Suitability Index (HSI)
  - Iterative Hierarchical Cluster Analysis (iHCA)

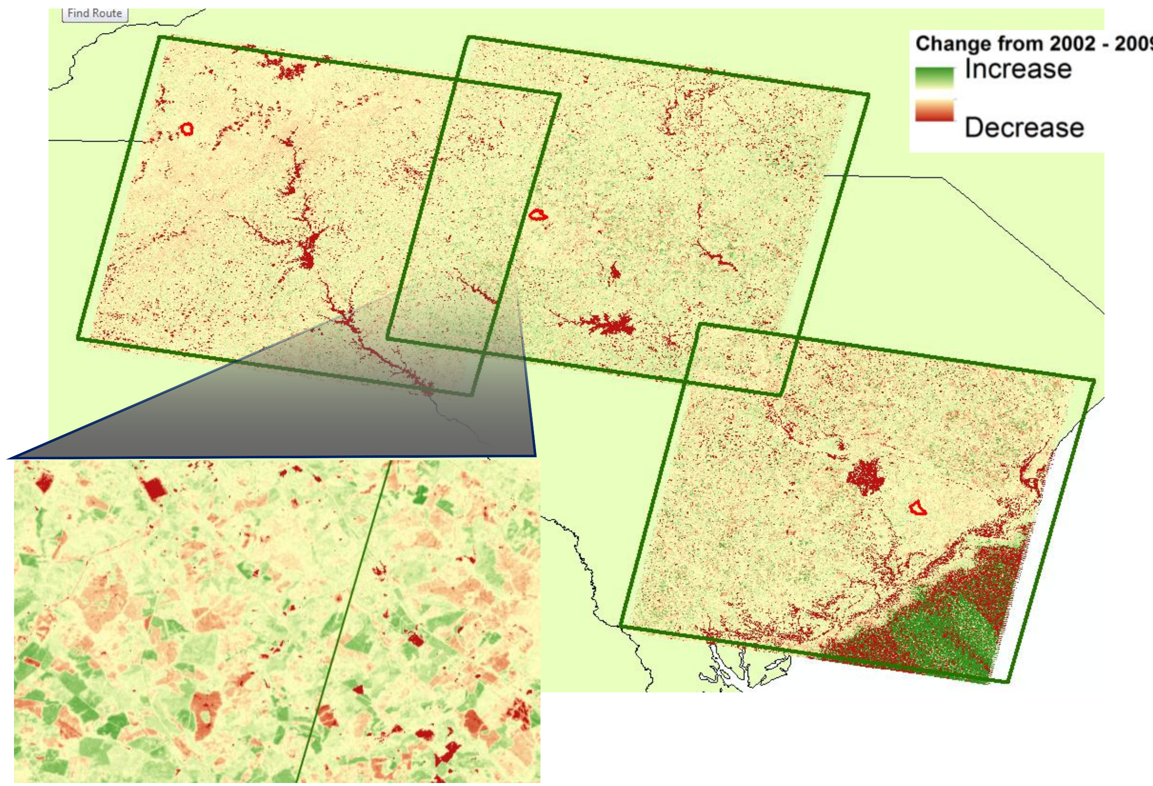
Tropical EWMACD

- Focus on 2002-2013 to better match Google Earth imagery for rough validation
- Variety of interesting change features detected



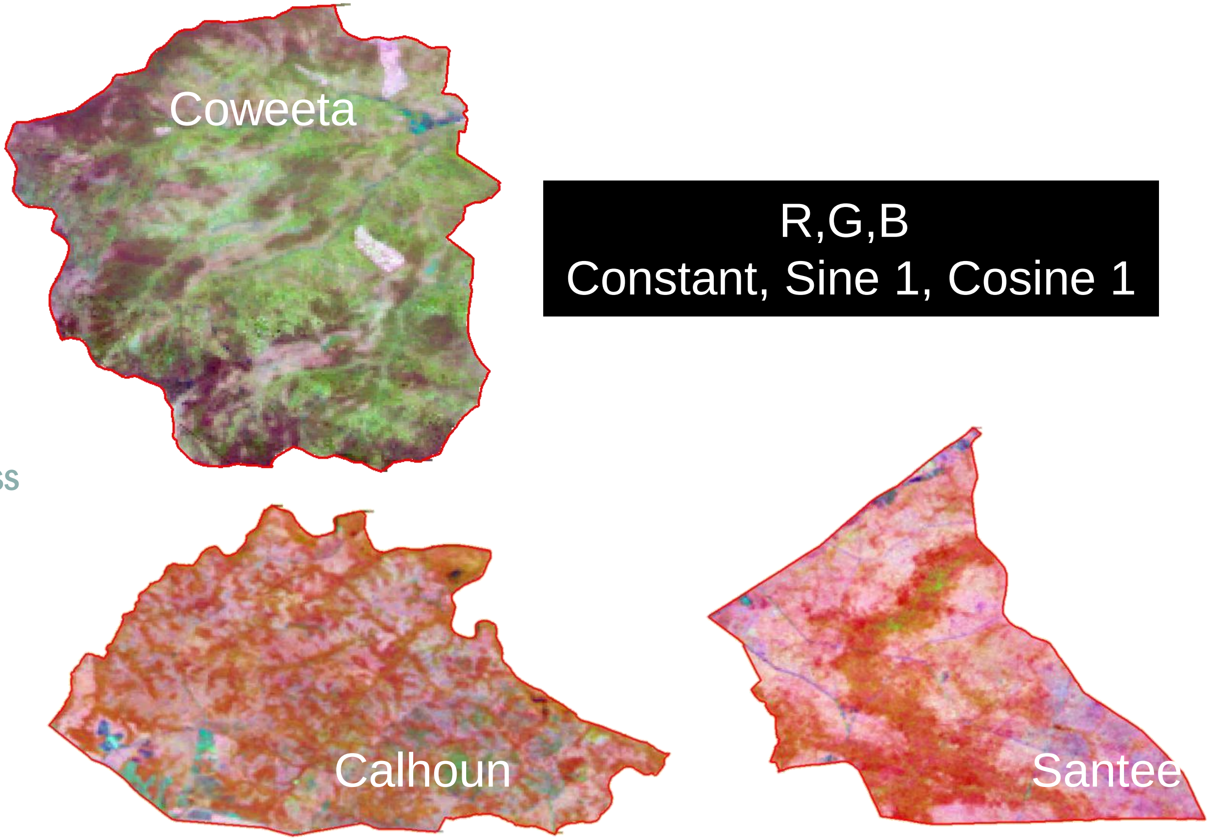
FIA and Landsat – Vegetation Cover Change

- **Results**
  - Every Landsat image in 2010 and 2011
    - LEDAPS-processed (Masek et al., 2006)
    - Converted to NDVI
    - Fmask filtering (Zhu and Woodcock, 2012)
    - 2-harmonic curves (Brooks et al., 2012)
  - Comparison to FIA plot observations is pending...



FIA and Landsat

- **Results**
  - Coefficients do a reasonably good job of predicting most carbon-related measurements
    - Carbon above ground, Carbon below ground, Carbon in litter, dry biomass in the crown
  - Other associations include stand age, stand species type, and type of recent disturbance



R,G,B
Constant, Sine 1, Cosine 1

Harmonic Suitability Index

- Driving Idea: A single-number statistic, computed solely from temporal information of a stack of images, that gives a sense of how appropriately a harmonic curve will be able to fit that stack
- Applications: Virtually anywhere harmonic regression is used
  - Retraining after disturbance signals, automated computing from incoming data

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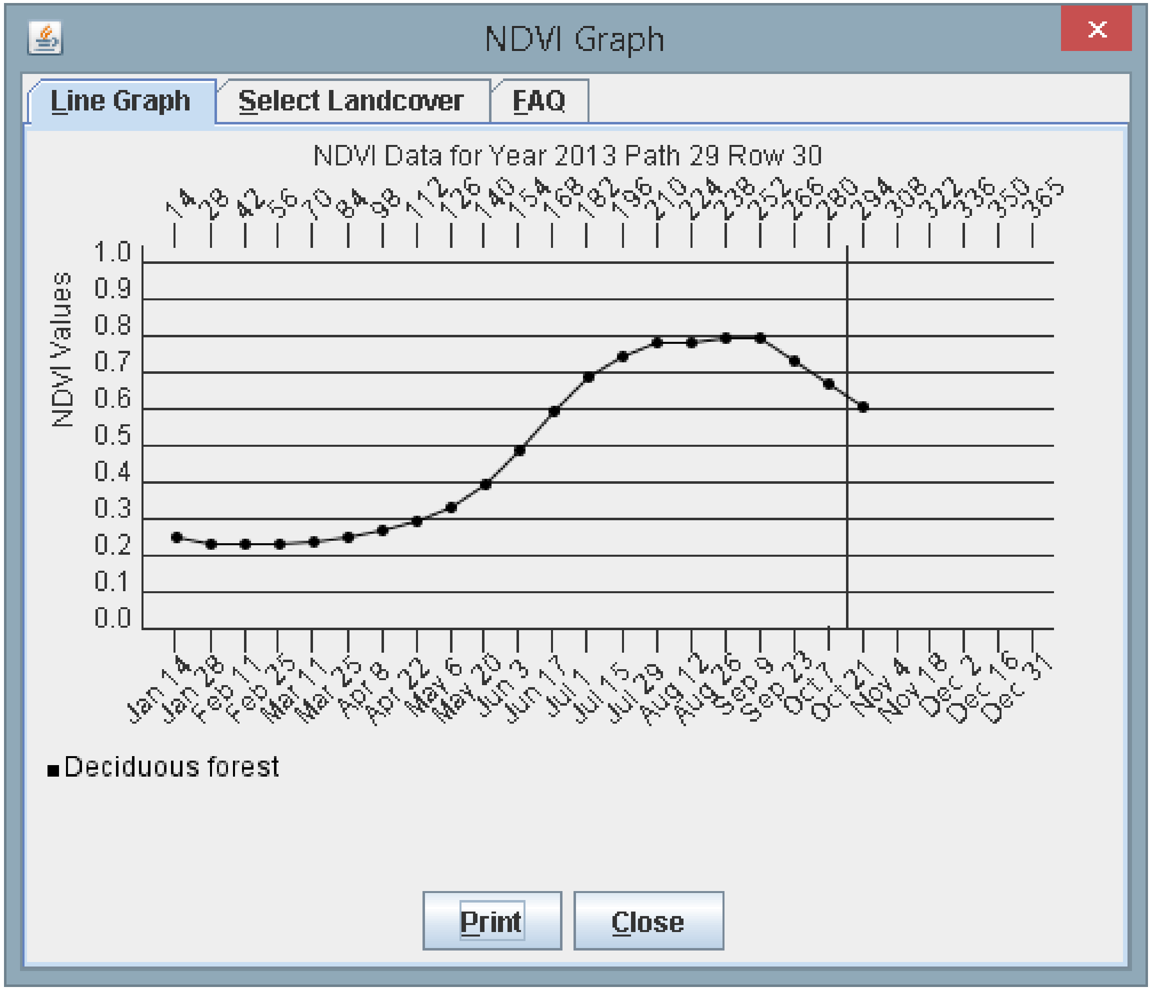
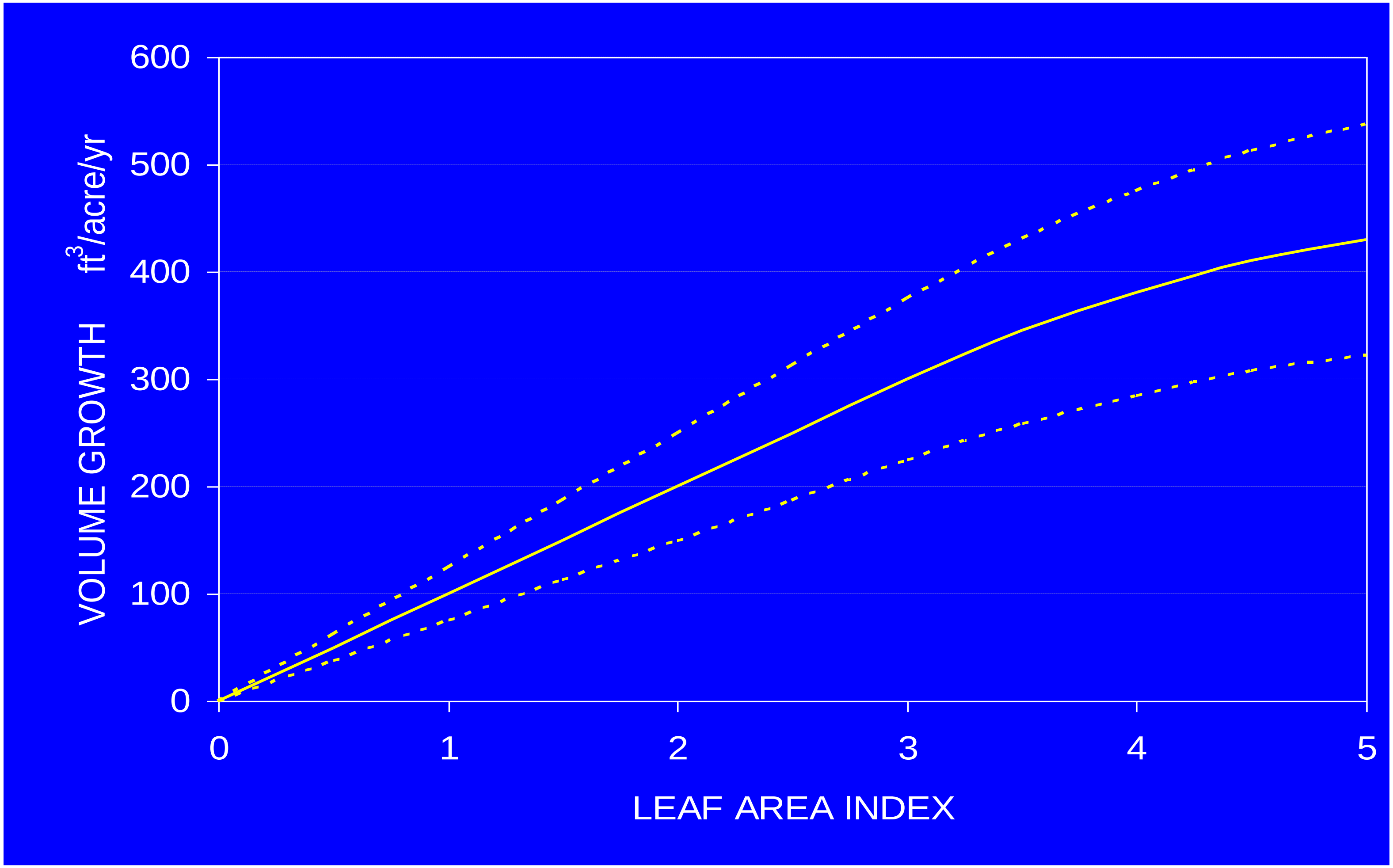
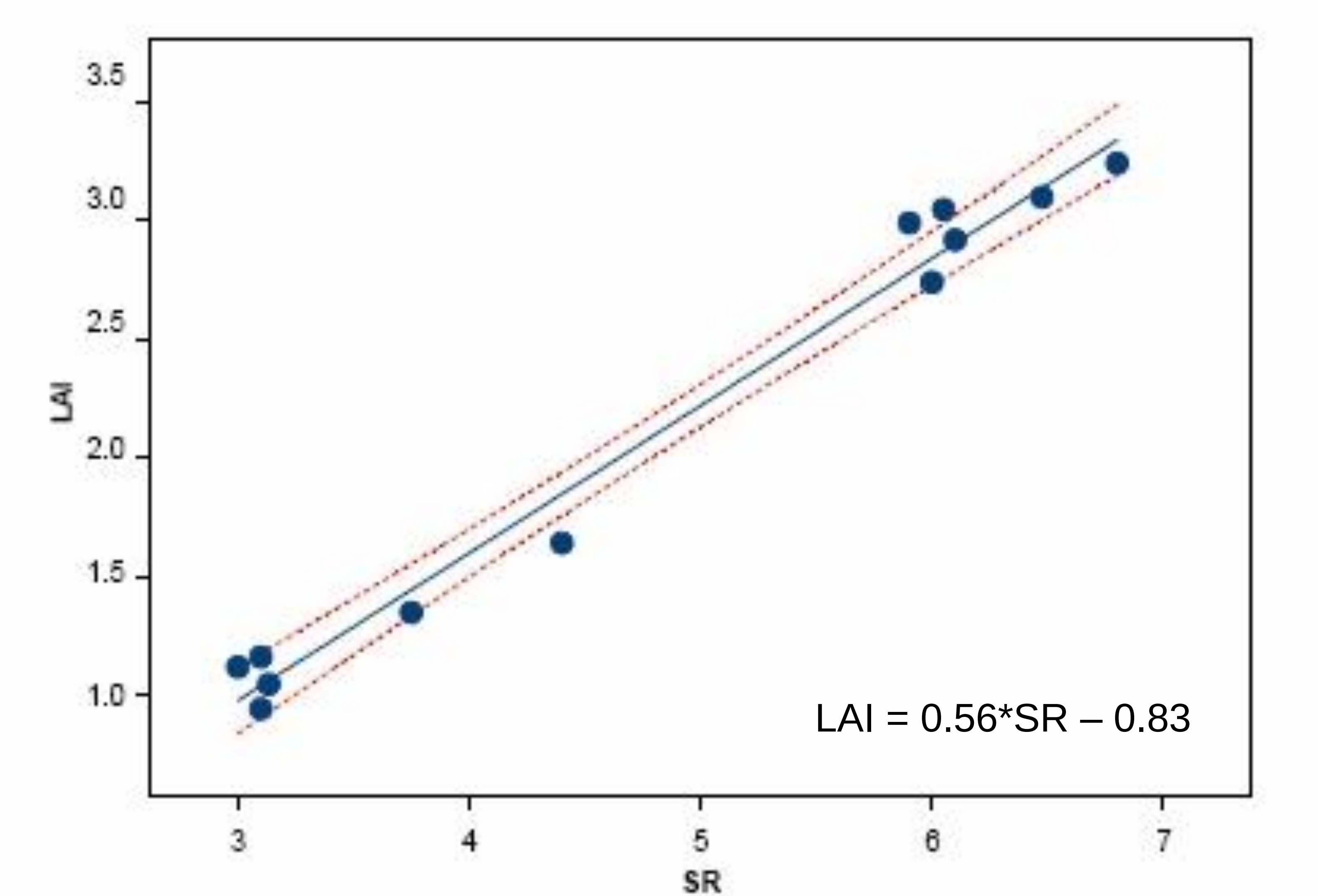
And if it is NOT suitable?



LAI is Related to Tree Growth

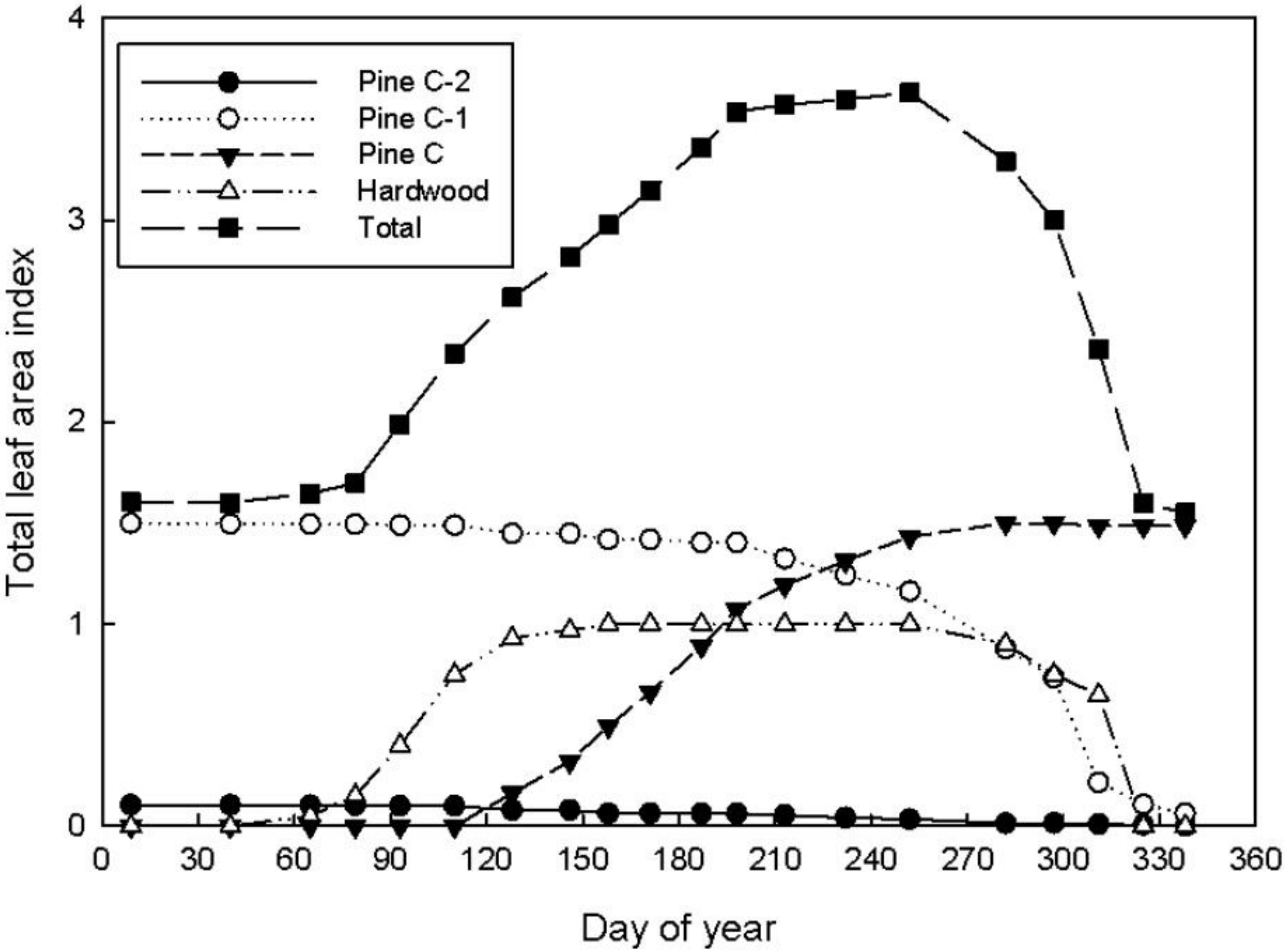




SR = simple ratio vegetation index (Landsat 7)

Flores et al. 2006

Loblolly Pine LAI Dynamics



Where:

Pine C-2 = 2-year old needle cohort

Pine C-1 = 1-year old needle cohort

Pine C = current year needle cohort

Hardwood = hardwood LAI

Total = total LAI

Blinn et al. 2012

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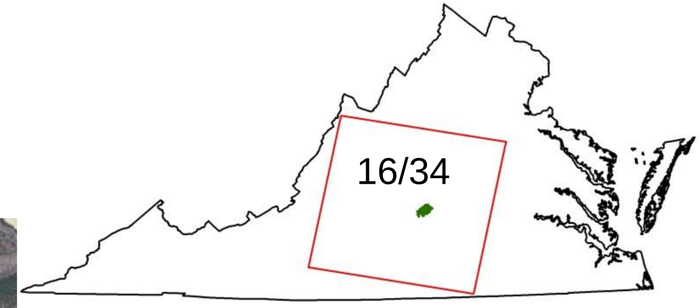
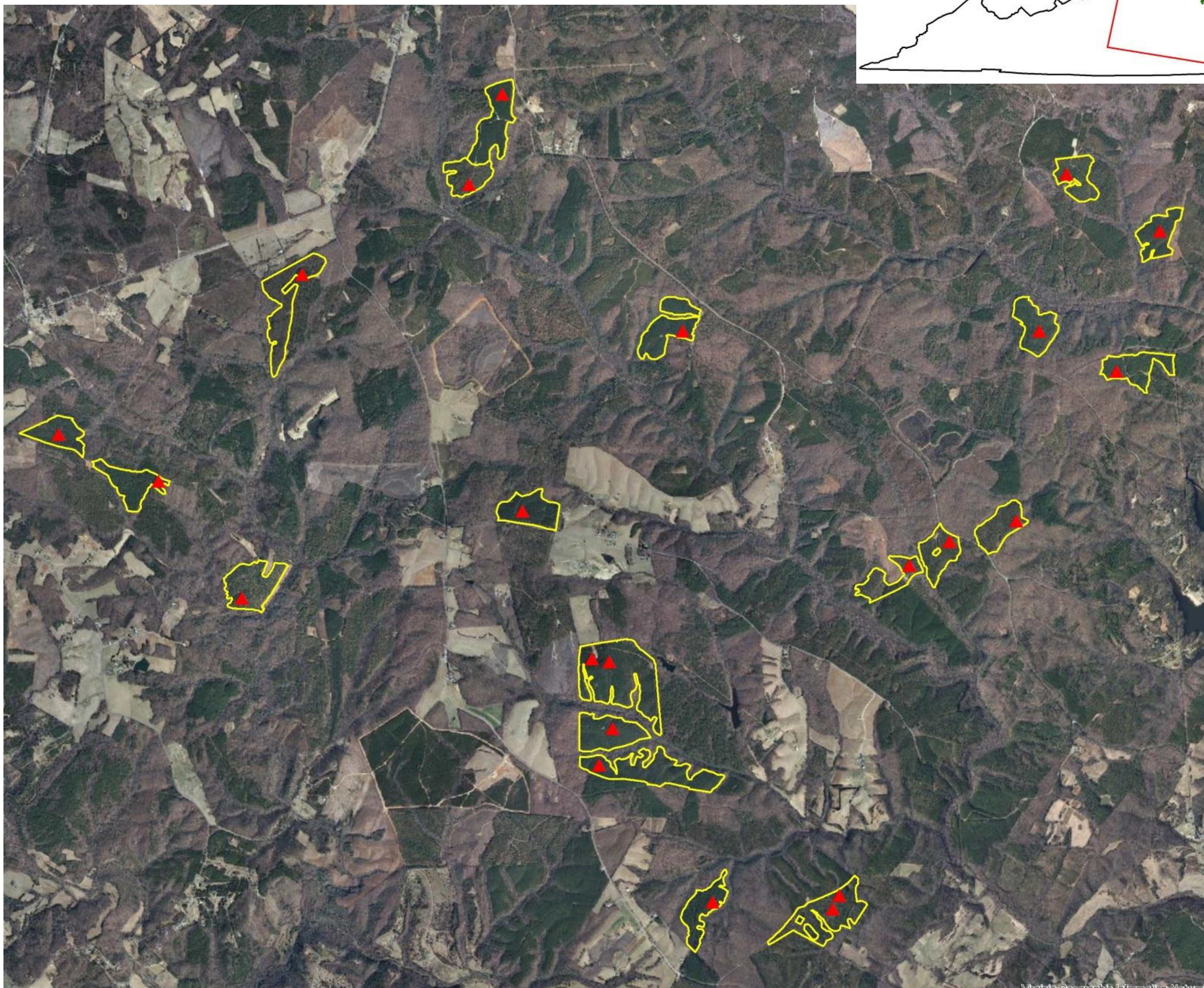
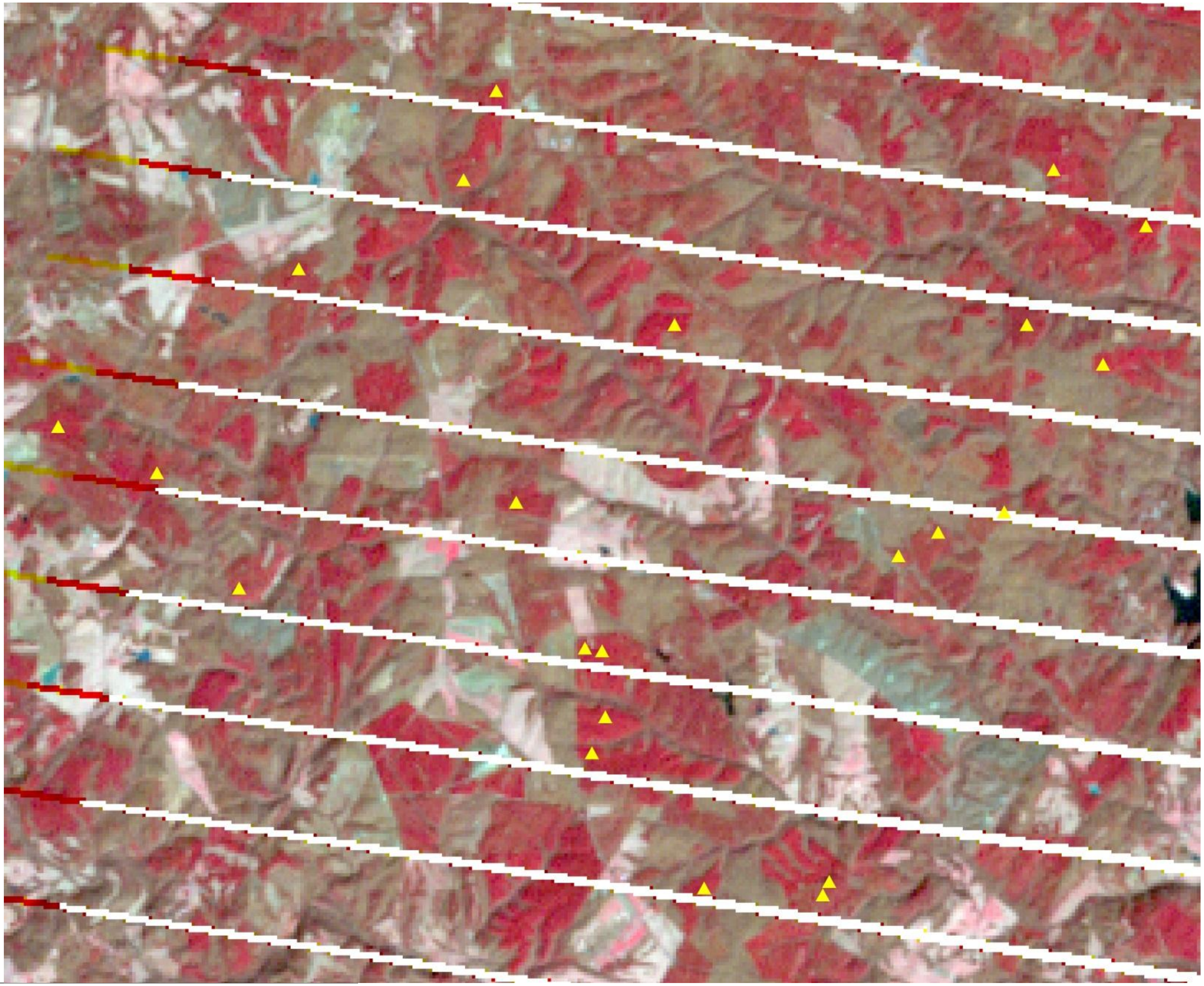


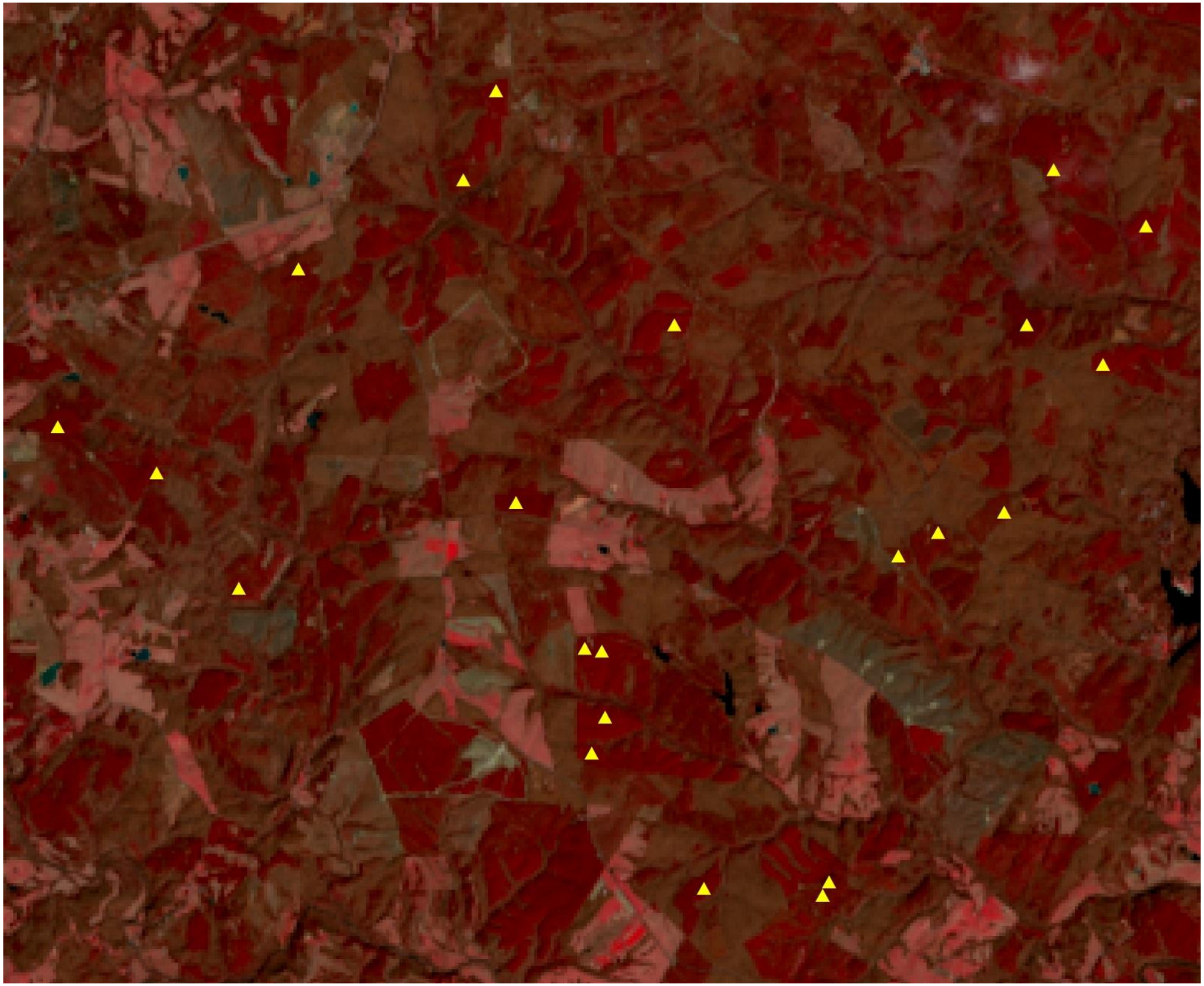


Landsat 7 w/Plots

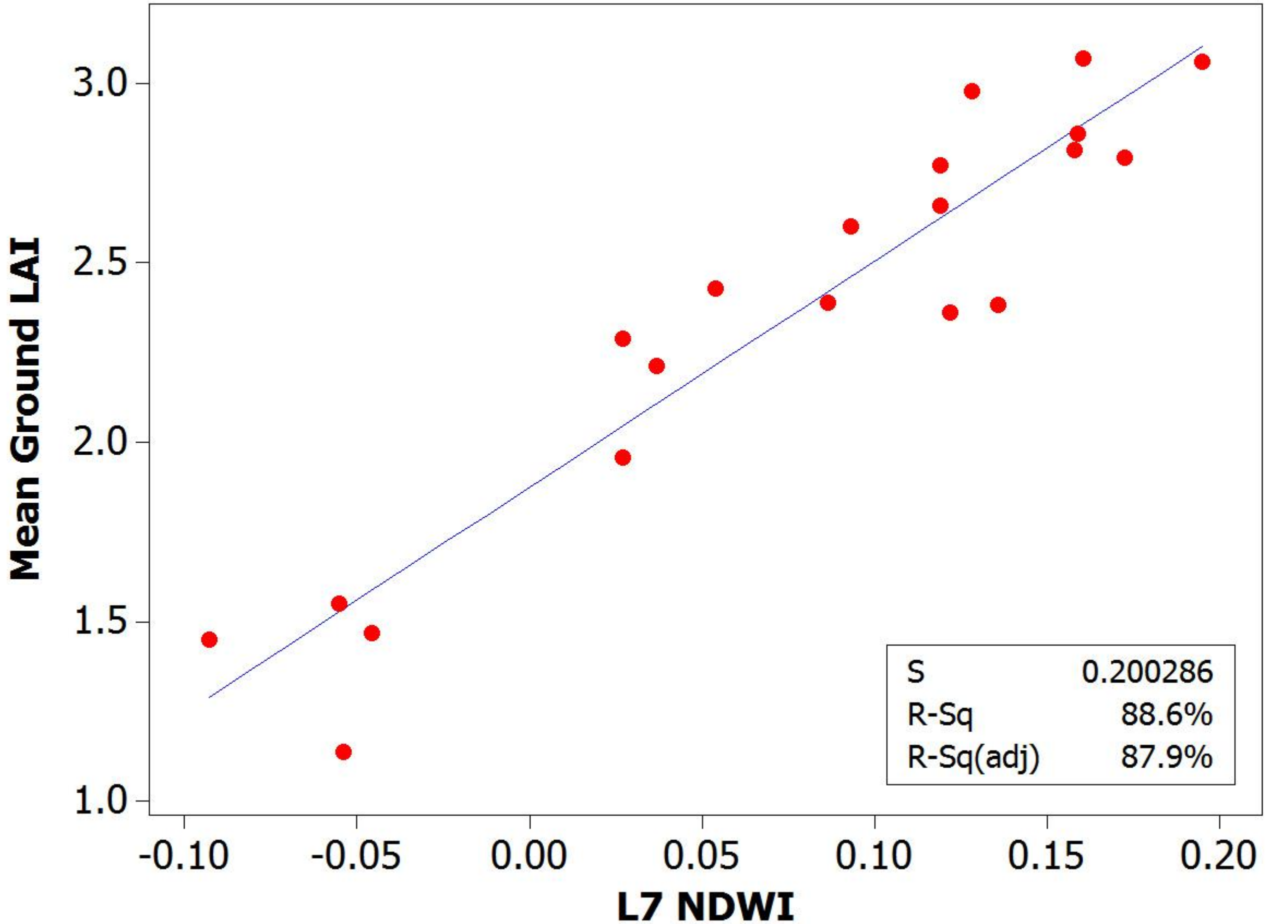


Feb. 15, 2013

Landsat 8 w/Plots

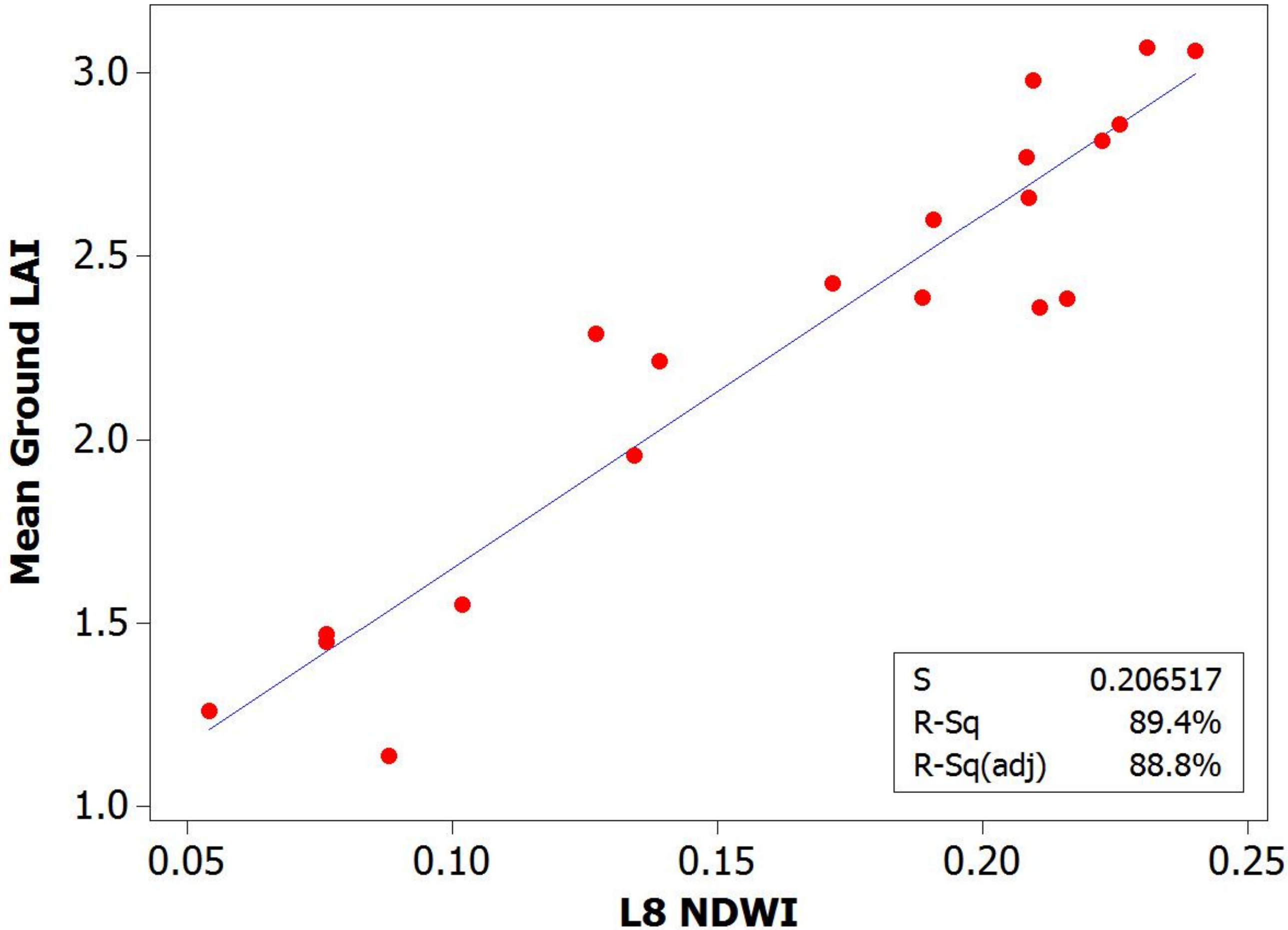


April Results L7



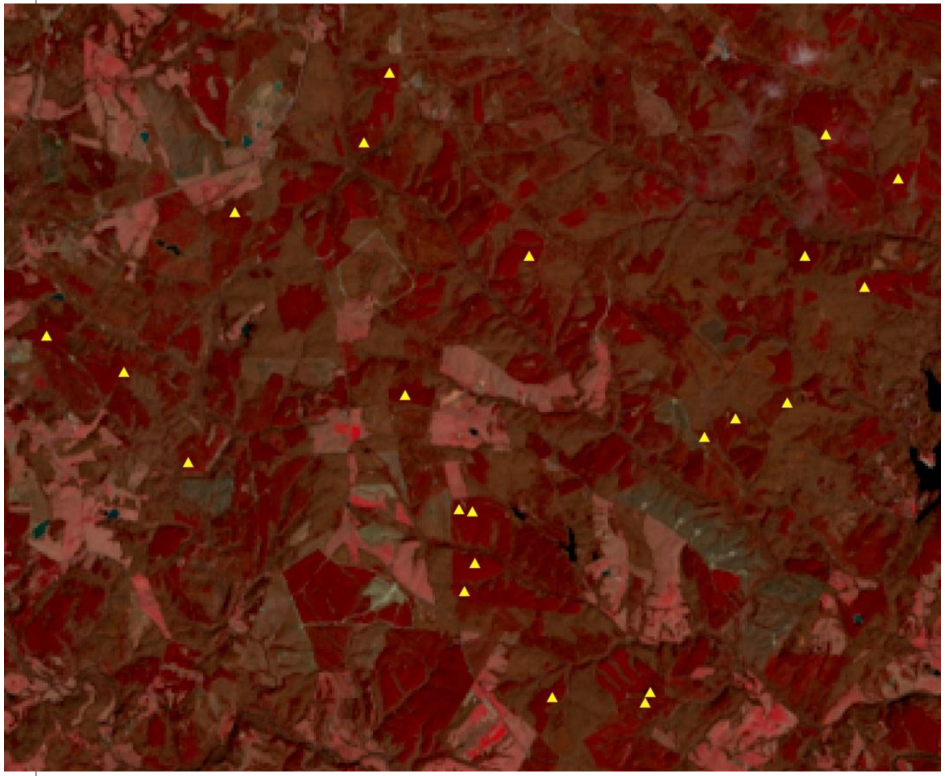
Note: only 19 of the 20 plots are the same for both L7 and L8

April Results L8

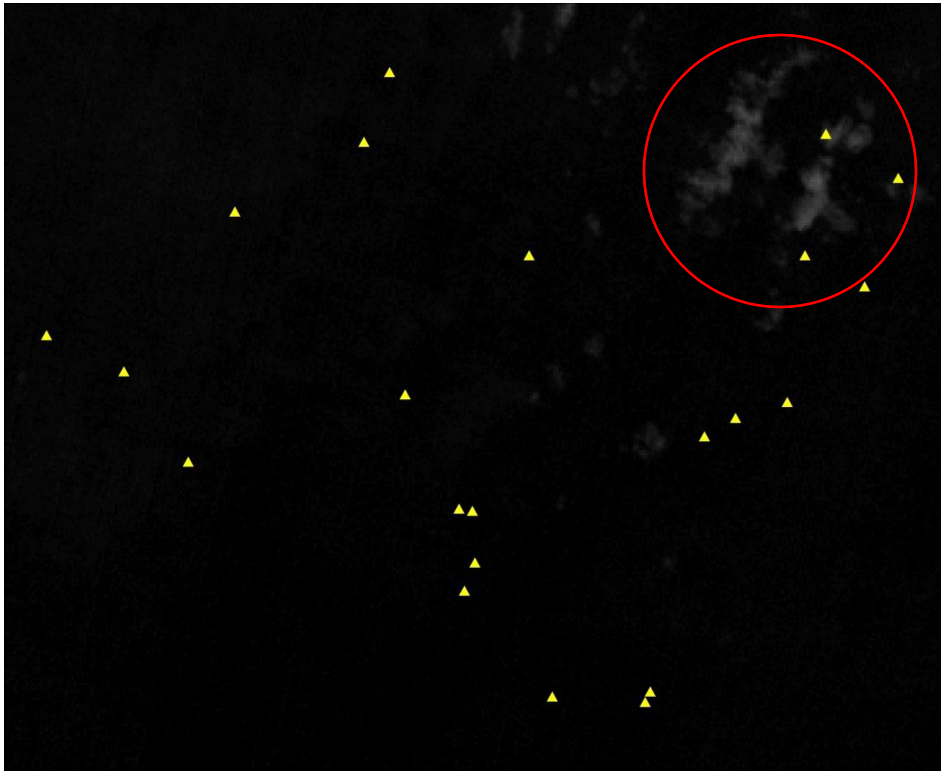


Note: only 19 of the 20 plots are the same for both L7 and L8

Landsat 8 Cirrus Band



Color-infrared band combination



Cirrus Band

March 28, 2013

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Accomplishments/Findings

- Installed a set of permanent plots at one study site for monitoring LAI
- NDWI might work better than other VIs when water availability is high
- Image timing less critical at minimum LAI, but very important at peak LAI
- L8 super tool for empirical LAI estimation

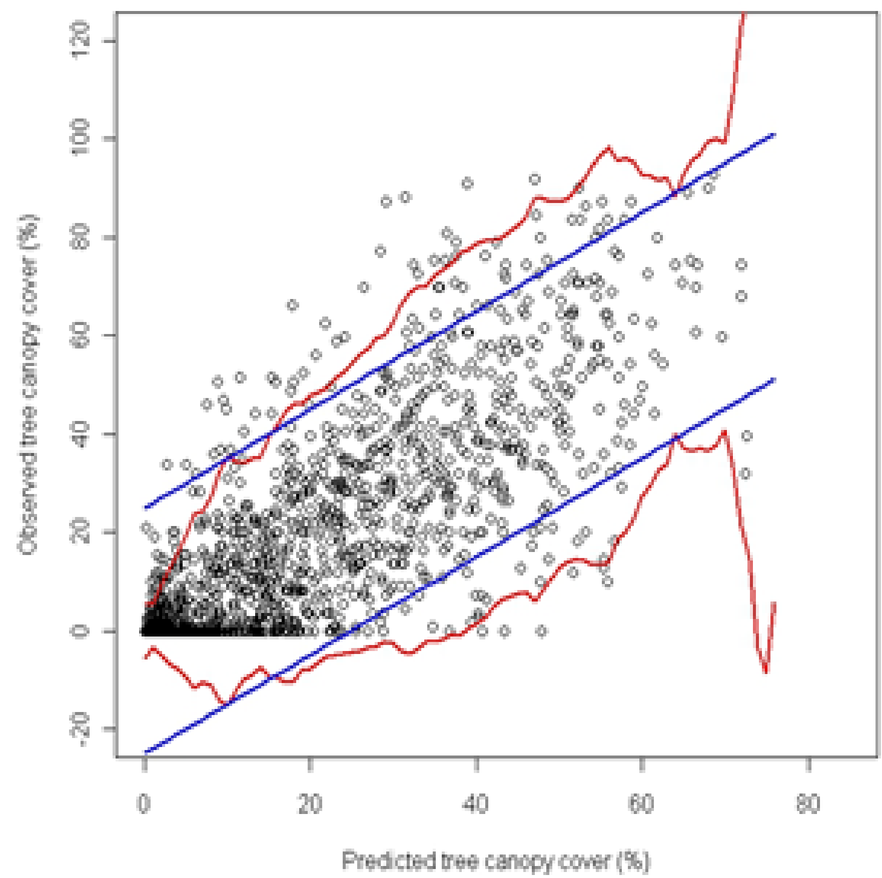
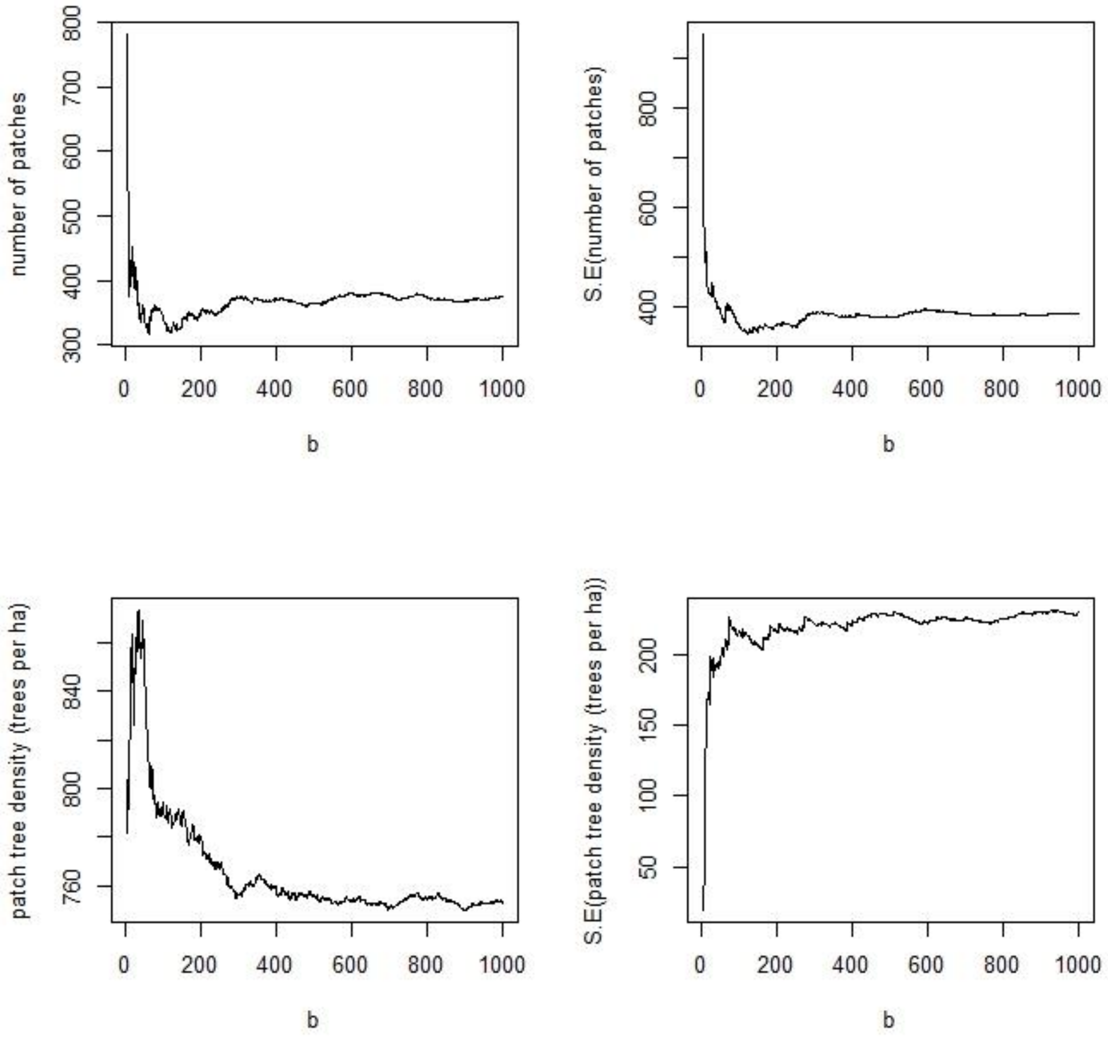
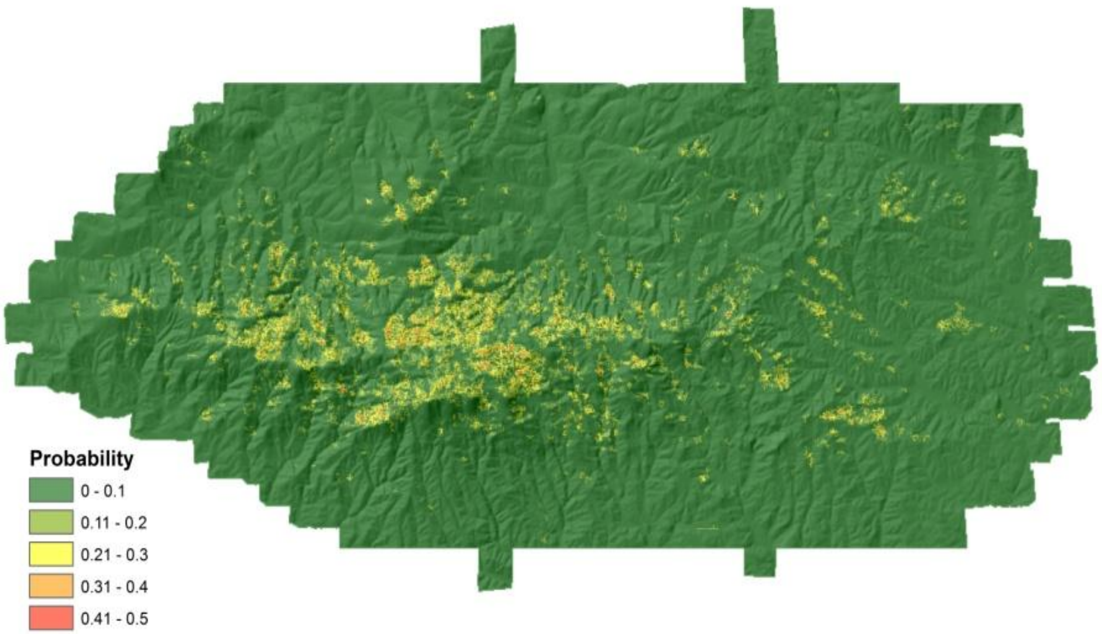


Figure 10 Example of Monte-Carlo 95% confidence intervals for a random forest model (red) as compared to standard bootstrap 95% confidence interval (blue) for percent tree canopy cover in a sparsely vegetated area of Utah. Note the standard bootstrap confidence intervals are too narrow in parts of the distribution and too wide in other parts of the distribution.



Mean and standard error of the mean for the number of patches and patch tree density based on b bootstrap samples



Likelihood of each pixel being part of a 1 ha patch with at least 5 species present, Moscow Mountain

Summary I

- Crowd sourcing a potential solution to removing remnant clouds and cloud shadows using L8 data – but has myriad science applications
- Smooth periodic time series generated from Fourier regression enable
  - Substantial data reduction
  - On-the-fly change detection using control charts
  - Use of harmonic coefficients for continuous and categorical data analysis
  - Need to know where it can’t be done and then what

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Summary II

- Both minimum and maximum LAI well predicted by empirical models using Landsat 8, though NDWI surprisingly best index
- The precision of vegetation continuous field products can be estimated in a robust and computationally-efficient manner using Monte Carlo or bootstrapping methods (kNN/MSN or Random Forests)